Quadcopter See and Avoid Using a Fuzzy Controller

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Unmanned Aerial Vehicles (UAVs) are fast growing sector. Nowadays, the market offers numerous possibilities for off-the-shelf UAVs such as quadrotors. Until UAVs demonstrate advance capabilities such as autonomous collision they will be segregated and restricted to flight in controlled environments. This work presents a visual fuzzy servoing system for obstacle avoidance using UAVs. To accomplish this task we used the visual information from the front camera only. This image is processed off-board and the information is send to the Fuzzy Logic controller which then send commands to modify the orientation of the aircraft. Results from flight test are presented with a commercial off-the-shelf platform.

1. Introduction

In the last decade the number of aerial platforms in the market has been steadily increasing. Small UAVs such fixed-wing, helicopters, quadcopters, octocopters, etc are now available in many toy stores. They are cheap, easy to use and easily interfaced with most smartphones like the AR-Drone-Parrot.[1] There are also more sophisticated models such as the ones offered by Ascending Technologies.[2] The potential use in civilian tasks gives to these platforms the opportunity to become principal players for applications such as surveillance, monitoring, vigilance and inspection,[3,4] Before their adoption in civil airspace the see and avoid problem -among others- must be addressed first. Some authors have proposed approaches to this problem.[5]

There exist numerous control techniques for quadcopter control but particularly to our application, Soft-Computing techniques offer some advantages such as model-free implementation (these techniques works well even when dynamic model to control is unknown) and easy controller tuning procedures. These advantages make these techniques an attractive approach for the researchers in the area of field robotics.

The paper is organised as follows. The visual algorithm that uses color detection to identify the obstacle to avoid, is presented in Section 2. The visual servoing approach using a heading controller developed with Fuzzy Logic, is described in Section 3. The behaviour of the controller in real tests with an AR.Drone-Parrot quadcopter are presented in Section 4. Finally, conclusions and future works are presented in Section 5.

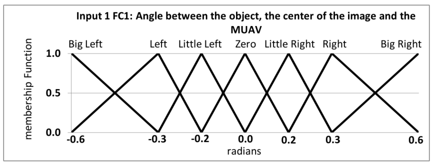
2. Visual System

In order to get feedback of the environment, the front camera of the quadcopter is used. The visual information is sent to the ground station for visual processing, then the outcome of this processing is used for control purposes. The obstacle avoidance task using visual servoing is based on the idea of detecting the object to avoid, track it keeping it at the right or left side of the image until a maximum yaw angle is reached and the object is overtaken. We approach the problem of tracking by exploiting the colour characteristic of the target. The target used has a particular color (orange) that then is tracked on consecutive images. The Camshift algorithm is used to track a defined color on an image sequence. This process is deeply explained in.

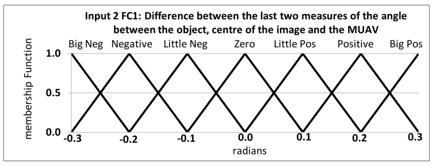
3. Fuzzy Controller

For the control of the aircraft we developed a controller that send yaw commands to the aircraft. This section describes this controller.

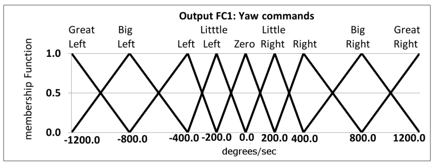
The controller is based on Fuzzy Logic and was implemented using the Miguel Olivares' Fuzzy Software (MOFS). This software has been used in a wide range of control applications in aerial[6] and mobile robots.[7] Detailed information of this software can be found in.[8] The yaw controller has two inputs and one output. The first input is angle between the quadcopters, the object to avoid and the right or the left side of the image, as shown in Figure1(a). The second input is the measure the evolution of this angle between the last two frames, as is shown in Figure1(b). The output of the controller is the desired yaw angle that the quadcopter need to turn to keep the object at the desired position, see Figure 1(c).



(a) First input. Estimation of the deviation of the object from the centre of the image capture from the MUAV.



(b) Second input. Difference between the last two measures.



(c) Output. Velocity commands to change the heading of the MUAV

Fig. 1. Definition of the Yaw controller.

4. Results

Flight test were conducted using Parrot-AR.Drone platform. Communication routines were deloped to send and receive information from the vehicle. A typical orange traffic cone was selected as the object to avoid. We used a VICON motion tracking system[9] to record accurately the trajectory of vehicle with the maximum precision. This information was used for 3D plotting, and no data was used for the control of the aircraft. As mentioned before in this paper, the only information used by the Yaw-controller is the visual information.

4.0.1. *Quadcopter System*

The quadcopter system used for this work is the commercial Parrot AR.Drone. This is a four-rotors aircraft with two cameras onboard, one at the front (forward-looking) which has been used in this work, and other at the bottom (downward-looking). The aircraft is connected to a ground station by a wi-fi connection. A extended explanation of this platform is presented in.[1] Figure 2 shows the control loop.

4.0.2. *Flight Test*

In similar way to simulations, flight test were performed with constant forward speed (constant pitch angle). No roll commands were sent during

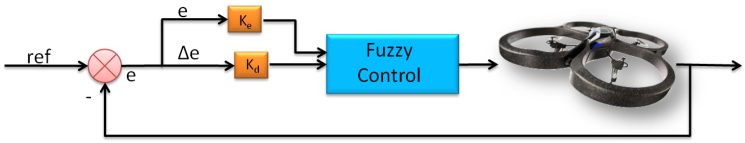


Fig. 2. Control Loop.

the experimets. The altitude was set to a constant value of $0.8m$ and is was controlled by the internal altitude controller of the AR.Drone.

The position of the quadcopter is calibrated at the beginning of the test, being the initial position the point $(0, 0, 0)$ meters. The obstacle to avoid is located in front of the initial position of the quadcopter at distance of 6 meters and at 1.1 meters from the floor $(5, 0, 1.1)$ meters. Little variations of no more that 10 cm at the initial position of the quadcopter were observed during the executions of different tests. In the Figure 3 the 3D flight reconstruction is shown. These tests were made at the indoor flying laboratory at the Australian Research Centre for Aerospace Automation(ARCAA).

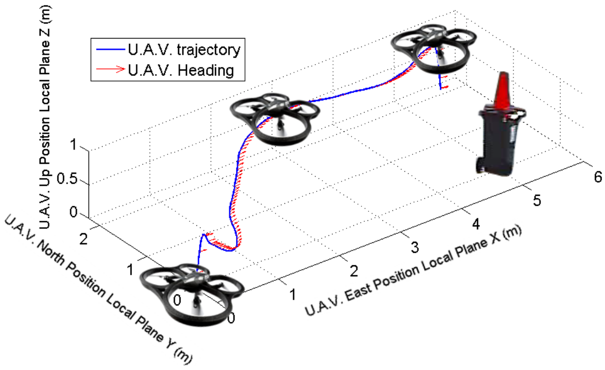


Fig. 3. 3D flight reconstruction of the flight path. The obstacle to avoid is a orange traffic cone located at the position (5,0,1.1).

Once the quadrotor takes-off, it flies for 1 meter towards the obstacle in open loop. Then the control process is activated, and then during the next following 5 seconds the controller is sending commands to the aircraft. The image processing and control task are finished after the quadrotor reaches its maximum allowable yaw angle. After this point the aircraft will go forward without any yaw commands. The Figure 4 shows some images captured from the onboard camera during the execution of this test. The Figure 4(a) shows when the motors have not been ignited. The Figure 4(b) shows the beginning of the test during the first meter without control. The Figures 4(c) and 4(d) shows two frames during the control process, and the Figure 4(e) shows when the quadrotor is overtaking the obstacle. A full video of the test can be found at[10] and[11] .

(a) (b) (c) (d) (e)

Fig. 4. Onboard images taken during the execution of the test. Figures 4(a) and 4(b) are previous to the control activation. Figures 4(c) and 4(d) are during the control process and Figure 4(e) is when the obstacle has been overtaken.

The behavior of the controller is represented in the Figure 5 which shows the evolution of the error during the test. The red line step represent the moment in which the image processing start. The measure of the step is 25 degrees, but at the moment when the step is applied the aircraft was looking at the opposite side increasing the step command to 35 degrees. To evaluate the behavior of the controller we use the error estimator of the root mean-square error (RMSE). The lower value this error estimator of $RMSE = 9.57$ degrees. The quick response of the controller shown in this Figure corroborate the excellent behavior of the optimized-controller.

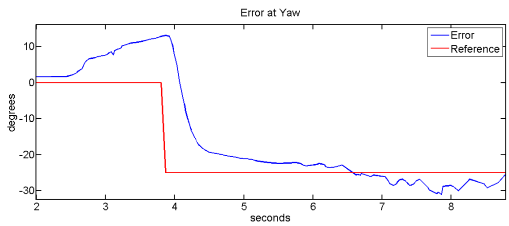


Fig. 5. Evolution of the error during a real test.

5. Conclusions

This paper presented a micro-UAV visual servoing approach for see-and-avoid. A Fuzzy Logic controller has been developed to automatize the collision avoidance. This controller acts changing the heading of the aircraft, keeping the obstacle to avoid at the right side (or left) of the image until the object can be overtaken. Excellent results have been obtained in real tests using the commercial quadcopter AR.Drone-Parrot with a quick response and a low error estimation. We are in the process to extending this approach to 3D, adding altitude control. Also, we plan to study different optimization algorithms to improve the controller and reduce the RMSE.

Acknowledgment

The work reported in this paper is the consecution of several research stages at the Computer Vision Group - Universidad Politécnica de Madrid and at the Australian Research Centre for Aerospace Automation - Queensland University of Technology (ARCAA-QUT). The authors would like to thank to Caja Madrid for the mobility research grant of one of the authors. This work has been sponsored by the Spanish Science and Technology Ministry under the grant CICYT DPI2010-20751-C02-01 and by the IRSES Program Marie Curie FP7 - PIRSES-GA-2009-230797 - ICPUAS (International Cooperation Program for Unmanned Aerial Systems Research and Development).

References

1. Ar.drone parrot http://ardrone.parrot.com, (2010).
2. Ascending technologies http://www.asctec.de, (2010).
3. O. Meister, N. Frietsch, C. Ascher and G. Trommer, Adaptive path planning for a vtol-uav, in *Position, Location and Navigation Symposium, 2008 IEEE/ION*, may 2008.
4. A. Moses, M. Rutherford and K. Valavanis, Radar-based detection and identification for miniature air vehicles, in *Control Applications (CCA), 2011 IEEE International Conference on*, sept. 2011.
5. L. Mejias, S. McNamara, J. Lai and J. J. Ford, Vision-based detection and tracking of aerial targets for uav collision avoidance, in *IEEE/RSJ International Conference on Intelligent Robots and Systems*, 2010.
6. M. Olivares-Mendez, I. Mondragon, P. Campoy and C. Martinez, Fuzzy controller for uav-landing task using 3d-position visual estimation, in *Fuzzy Systems (FUZZ), 2010 IEEE International Conference on*, july 2010.
7. M. Olivares-Mendez, I. Mellado, P. Campoy, I. Mondragon and C. Martinez, A visual agv-urban car using fuzzy control, in *Automation, Robotics and*

Applicatios (ICARA), 2011 IEEE International Conference on, December 2011.
8. I. Mondragón, M. Olivares-Méndez, P. Campoy, C. Martínez and L. Mejias, *Autonomous Robots* **29**, 17 (2010), 10.1007/s10514-010-9183-2.
9. VICON, www.vicon.com (2012).
10. Computer vision group-upm http://www.vision4uav.eu, (2012).
11. Youtube channel computer vision group-upm http://www.youtube.com/colibriprojectUAV, (2012).